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EXPERIMENTAL INVESTIGATION OF WEAR RESISTANCE OF MODELS HARD FACED WITH VARIOUS FILLER METALS

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Abstract: *Hardness, microstructure and wear resistance of hard faced models, executed by application of four different kinds of filler metals, are analyzed in this paper. The objective of this work is to show which filler metal is the best for hard facing, from the aspect of laboratory checking of the wear resistance. Models that were hard faced, were made of low carbon steel, primarily from the reason to save the expensive base metal, but also to analyze the possibilities for extending the service life of structural parts. Hard facing was done in three passes/layers, by the MMAW procedure, with use of various filler metals. Those were filler metals aimed for hard facings of parts exposed to intensive wear. Three samples were hard faced without the interpass, while on one sample the interpass was deposited by the austenite electrode. After the hard facing, the metallographic slits and blocks were prepared, aimed for the hardness measurements, investigating the microstructure and tribological investigations. Hardness was measured in three directions, while the microstructure was red-off in all the zones of the hard faced layers: base metal, heat affected zone and in the weld metal. Tribological investigations were performed on blocks made of pure weld metal, in order to determine the friction coefficient and the wear scare. The wear scare width was used as a parameter for estimates of the wear resistance of models, with previous metallographic investigations and hardness measurements.*

Keywords: *hard facing, filler metals, hardness, microstructure, friction coefficient, wear scare width.*

1. INTRODUCTION

Numerous working parts are during the exploitation exposed to various types of complex tribological processes and wear. It is hard to determine which of the wear mechanisms is the dominant one and which one leads to biggest damages. Usually, damages are consequences of coupled action of several wear mechanisms. That is why it is necessary to apply higher quality materials, which are resistant to wear and which can produce more working hours for the concrete machine part. Since manufacturing of large parts or the whole structures of high-quality materials would be too expensive, the problem could be solved by application of hard facing. It enables reparation of damaged parts or manufacturing of the new parts by depositing the high quality material of high hardness on the surface of the part made of the softer and cheaper material. In that way, one saves not only material and money, but also the time needed for revitalizing damaged parts, shortening the downtimes, etc. Hard facing also offers an opportunity to determine wear resistance of different filler materials. Our investigations [1-10] and investigations of other authors [11-14] have shown that worn and new parts can be successfully hard faced.

The objective of this work is to determine the mechanical properties (hardness and microstructure) and the wear resistance of the hard faced layers deposited with four types of the filler metals. All the tested materials were aimed for hard facing and for operating in conditions of extremely prominent wear. The base metal was low carbon steel S235 JRG2, while the filler metals used, were 1 – E DUR 600, 2 – E Mn17Cr13, 3 – CrWC 600 and 4 – interlayer INOX 18/8/6 and CrWC 600.

2. FILLER MATERIALS PROPERTIES

Selection of the filler metals was done based on the purpose of the hard faced parts and based on characteristics the material must possess. Based on the wear mechanism and by analyzing the wear process of any particular part it may be concluded that wear is the most often caused by friction, although sometimes the cause could be the corrosion, thermal or thermo-mechanical fatigue, etc. In the case of strong corrosion influence, filler metals must be chosen based on the chemical composition of material, which would be chemically resistant, but in the case of parts exposed to friction forces, selection of filler metal is more complex. However, hardness and chemical composition could not be the only criteria for estimation of hard facing material's serviceability. Filler metals for wear resistant hard facing may be classified in six classes, which are steel, cast iron (white), wolfram carbide, cobalt alloy, nickel alloy, and cooper alloy. In the most cases, industrial components cease to operate due to wear (53 % abrasive, 24 % adhesive, 10 % impact) and only in 13 % of cases due to corrosion. Therefore, the filler metals may be classified based on that criterion [1]. The chemical composition of the base metal – steel and the electrodes are given in Table 1 while mechanical properties and application of used filler materials are shown in Table 2.

Table 1. Chemical composition of base metal and filler metals

Steel/Electrodes	Alloying elements [%]									
	C	Si	Mn	P	S	Cr	Mo	W	Ni	Al
S235 JRG2	0.20	0.55	1.40	0.045	0.045	0.30	0.08	-	0.30	0.020
E DUR 600	0.50	-	-	-	-	7.50	0.5	-	-	-
E Mn17Cr13	0.60	-	16.5	-	-	13.5	-	-	-	-
CrWC 600	4.00	-	-	-	-	26.00	-	4.00	-	-
INOX B 18/8/6	0.12	0.80	7.00	-	-	19.00	9.00	-	-	-

Table 2. Mechanical properties and application of used electrodes

No.	Electrode designation	Application	Hardness
1.	E DUR 600	For high wear resistance hard facing, good toughness and resistance to impact and shear in both cold and hot environments.	57 – 62
2.	E Mn17Cr13	For hard facing of mallet of hydraulic presses, parts of loading bucket of construction mechanization, parts of crushing machines, railway tracks and crossbeams.	220 HB 48 HRC – after cold hammering
3.	CrWC 600	For very hard surfacing with high content of Cr and W carbides with high wear resistance in stones' machining, but with low level of impact and shear resistance.	57 – 62 HRC
4.	INOX B 18/8/6*	For welding of Cr and Cr-Ni steel and various steels, for hard facing resistant to corrosion and for deposition of plastic interlayer.	–

*Rarely used for hard facing, but the most often for placement of inter-layers and welding

3. EXPERIMENTAL INVESTIGATIONS

3.1 Hard facing technology

The first thing done within the experimental investigation was to make the hard faced models which would serve for testing and which could plausibly represent the real parts. Experimental hard facing of models is used to establish which hard facing technology is optimal. Models are hard faced with one or more passes (layers) with or without preheating (Figs. 1a, b and c). Hard faced models are used to cut the metallographic samples – blocks out of them, as shown in Figure 1d. Hardness has been measured on surfaces of blocks in different directions necessary to estimate the microstructure of characteristic surfaced zones. Samples were chosen to be geometrically similar to hard faced part and they were made either of well weldable steel Č0361 – S235 JRG2 [15]. The hard facing parameters are shown in Table 3.

Microstructures and characteristic of hard faced zones and surfaces, depending on the filler metal, were estimated as: martensite – carbide with residual austenite (E DUR 600), sorbite with perceived boundaries of austenite grains and uniformly distributed carbides (E Mn17Cr13), ledeburite (CrWC 600), and mainly austenite (INOX B 18/8/6) [1,2].

3.2 Tribological testing

Tribological investigations were performed in Laboratory for Tribology at Faculty of Engineering in Kragujevac by using tribometer TPD-93. The objectives of those tests were to determine the wear resistance of joint base metal-hard faced metal. Samples for tribological testing, as prismatic blocks with dimensions 6.5 × 15 × 10 mm, were taken from both surfaced and base metal. During the testing, “block on disk” contact has been realized. External variables were the contact force, sliding speed and lubricant. Motor oil GLX 2 SAE 15W-40 has been used as lubricant.

4. RESULTS

4.1 Hardness and microstructure

Hardness measurement was done along the three directions perpendicular to the hard faced layers’ surface, on samples prepared from the weld metal, according to Figure 1d.

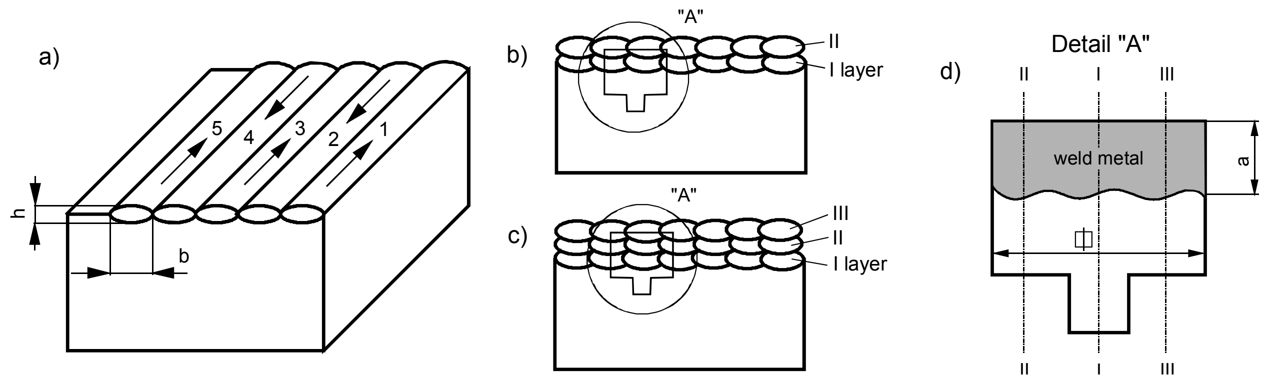


Figure 1. Order of layers deposition: (a) layer 1, (b) layer 2, (c) layer 3 and (d) metallographic ground slit

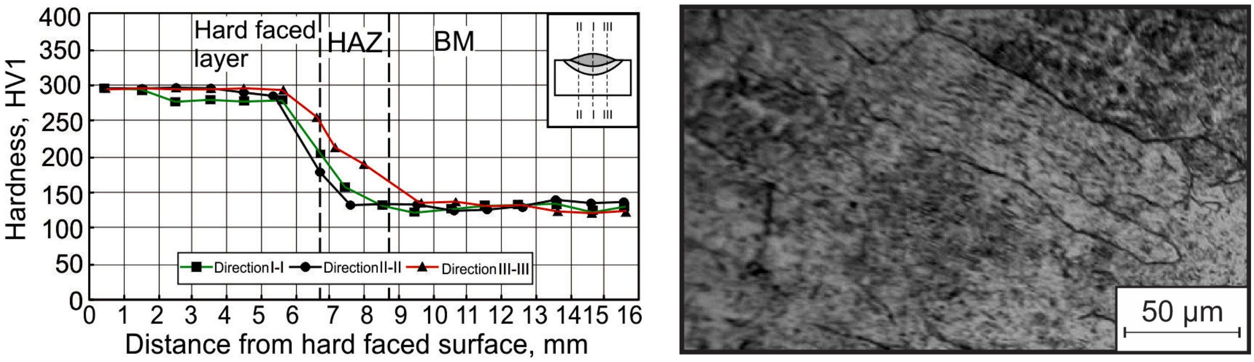
Table 3. Hard facing parameters for the MMAW procedure

BM thickness, s [mm]	Electrode designation by producer	Electrode core diameter, d_e [mm]	Hard facing current, I [A]	Voltage, U [V]	Hard facing speed, v_z, [cm/s]	Driving energy, q_l [J/cm]
10	E DUR 600	3.25-5.00	120-200	25-28	0.119-0.220	20168-25455
	E Mn 17 Cr 13	3.25-5.00	130-200	25-28	0.152-0.168	17105-26667
	Cr WC 600	3.25-5.00	125-220	25-29	0.116-0.180	21555-28356
	INOX B 18/8/6	3.25-5.00	100-140	24-26	0.136-0.178	14118-18696

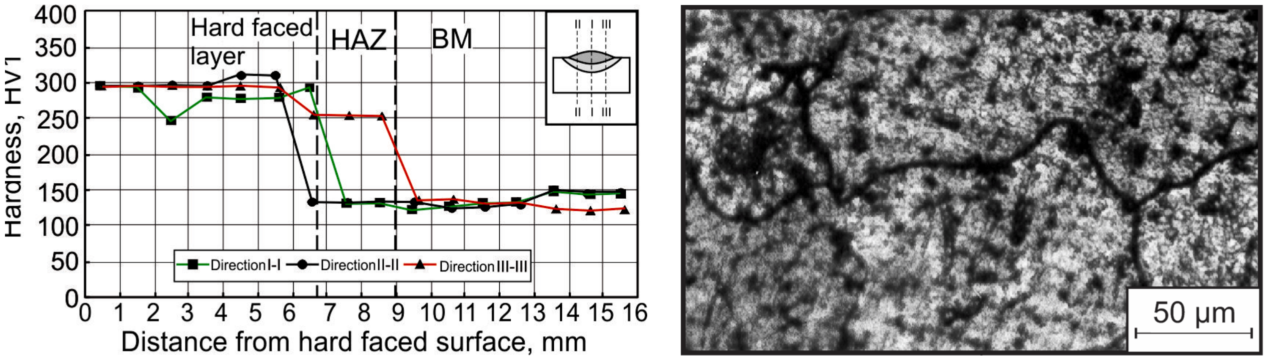
The measurement was done in all the zones of the hard faced layer (weld metal – WM, heat affected zone – HAZ and in the base metal – BM). Besides hardness, for every filler material, the microstructure is determined. Results are presented as diagrams in Figure 2.

4.2 Tribological investigations

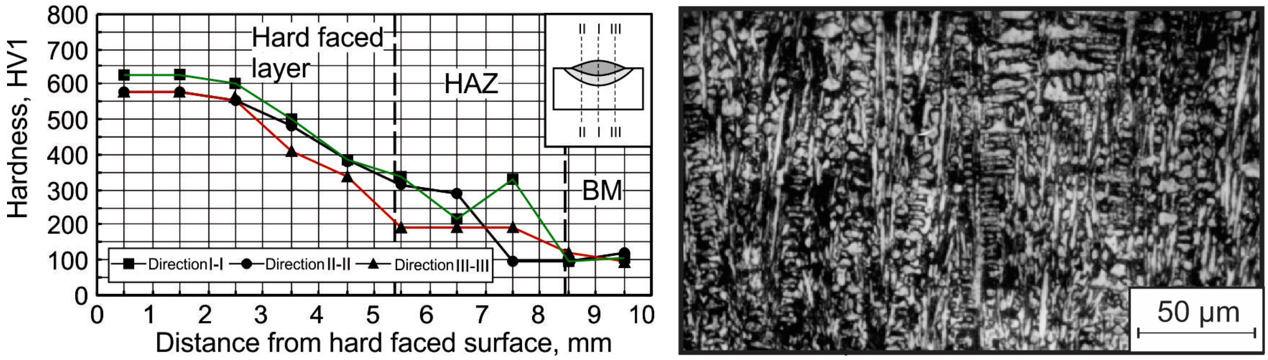
Prior to testing, the topography of discs and blocks has been measured on digital measurement system Talysurf 6.



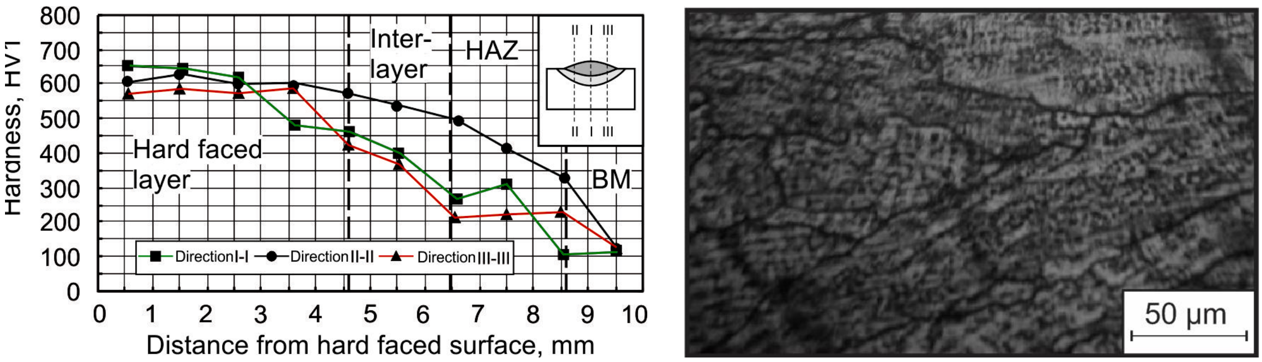
(a) E DUR 600



(b) E Mn 17 Cr 13



(c) CrWC 600



(d) CrWC 600; Interlayer INOX B 18/8/6

2 **Figure 2.** Hardness distribution and microstructure of four filler materials

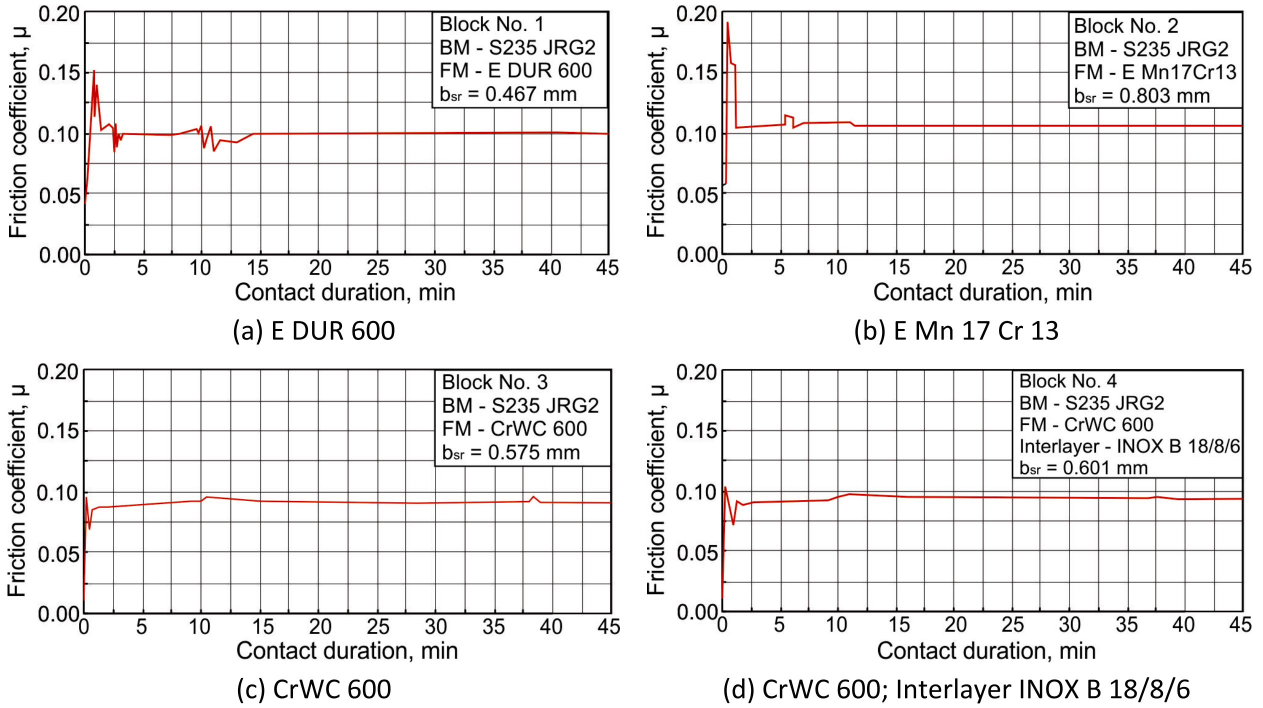
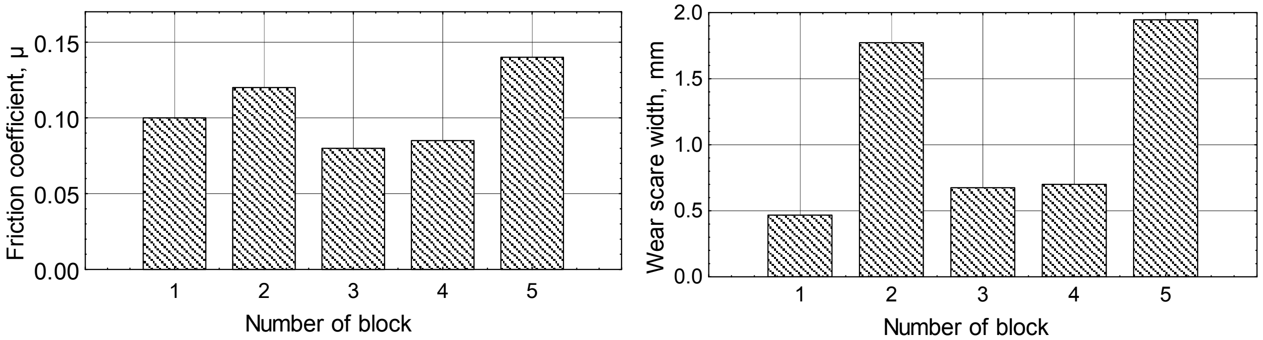


Figure 3. Friction coefficient distribution over the hard faced layer for four types of filler metals



Block 1 – E DUR 600; Block 2 – E Mn17Cr13; Block 3 – CrWC 600; Block 4 – CrWC 600 + Interlayer INOX B 18/8/6; Block 5 – S235 JRG2 (BM)

Figure 4. Histograms of mean values of friction coefficients (a), and wear scare width

Contact has been achieved with normal force F_N = 300 N and sliding speed v_s = 1 m/s.

During the contact of about 45 min variation of the friction coefficient (Fig. 3) and of the wear scare width (Fig. 4), have been recorded/measured. In this way, the tribological characteristics of blocks, made of the above mentioned materials, have been determined. Wear scare width was recorded by microscope UIM-21 - magnification 50 ×.

5. DISCUSSION AND CONCLUSIONS

By measuring the wear scare width and the friction coefficient, it was concluded that the hard faced layers deposited by E DUR 600 and CrWC 600 have much better wear resistance in comparison to layers deposited by E Mn17Cr13. By investigation of the base metal, it was established that steel S235 JRG2 has poor wear resistance and that the hard facing with selected filler metals was justified. However, by measuring widths of wear scares only, it could not be concluded that it is better to perform hard facing with electrodes E DUR 600 and CrWC 600 than with E Mn17Cr13. Effective wear resistance to different kinds of wear could be determined reliably only after testing in real working conditions.

Suitable selection of the hard facing technology leads to many advantages in comparison to installation of new parts like extension of life cycle of hard faced parts, increase of productivity, lowering the cost of supplies, shortening the downtime, etc. Directions for adequate selection of the filler metals, depending on kind and type of wear, are given in this paper. Measuring of micro hardness and checking of wear resistance led to determination of hard faced layers' quality. Model testing provided data necessary for selecting the best filler metal, optimum hard facing technology and relationship between the input and output parameters of the hard facing process.

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